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Tongue-pressure and submental surface electromyography measures during non-effortful and effortful saliva swallows in healthy women

Yeates, E. M.^{a1}, Steele, C. M.^{a,b} and Pelletier, C. A.^{c,d2}

Author affiliations:

a) Toronto Rehabilitation Institute, Toronto, Canada

b) University of Toronto, Toronto, Canada

c) University of Arkansas for Medical Sciences, Little Rock, AR

d) Johns Hopkins Hospital, Baltimore, MD

Contact Information:

Catriona M. Steele,

Toronto Rehabilitation Institute,

550 University Avenue,

Toronto, ON, M5G 2A2, Canada

Tel: 416-597-3422 ext. 7603

E-mail: steele.catriona@torontorehab.on.ca

¹ Now at the Saskatoon City Hospital, Saskatoon, Canada

² Now at the Walter Reed Army Medical Center, Washington, DC

Abstract

Purpose

The effortful swallow, a compensatory technique frequently employed by speech-language pathologists for their patients with dysphagia, is still not fully understood in terms of how it modifies the swallow. In particular, although age-related changes are known to reduce maximum isometric tongue-pressure, it is not known whether age affects people's ability to perform the effortful swallow. In this study, differences were explored between younger and older healthy women in execution of the effortful swallowing maneuver through a comparative analysis of effortful and non-effortful swallows.

Methods

Eighty healthy women (40 aged 18-35 years; 40 aged 60 years and older) participated. Peak amplitude measures and the timing of signal onset to peak were measured using concurrent tongue-pressure and submental surface electromyography.

Results

Statistically significant main effects of age-group were not observed in the amplitude data, but older participants showed slower rise-times to peak anterior tongue-palate pressure.

Conclusions

Despite the general age-related deterioration of the swallowing musculature due to the phenomenon of sarcopenia, older women can still produce non-effortful and effortful swallows with similar lingual pressure and submental EMG amplitudes to younger women.

Key Words

Deglutition; Electromyography; Manometry; Aging

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Introduction

A variety of different swallowing maneuvers are routinely recommended by speech-language pathologists to improve swallowing function or compensate for swallowing difficulty (Witte, Huckabee, Doeltgen, Gumbley & Robb, 2008). One such technique, the effortful swallow, is still not fully understood in terms of how it modifies swallowing function. To perform an effortful swallow, the client is typically instructed to “swallow hard” or “squeeze hard with all your swallowing muscles” (Logemann, 1997). This is intended to drive the bolus more efficiently through the pharynx; the expected outcome is a swallow with very little, or no pharyngeal residue (Coulas, Smith, Qadri & Martin, 2009; Logemann, 1997; Veis, Logemann & Colangelo, 2000). A number of studies have been published on the physiological effects of the effortful swallow maneuver, but their methods differ, including instructions regarding execution of the maneuver, and whether saliva or liquid swallows were recorded. Table 1 summarizes the results of these prior studies. Results are mixed, particularly regarding the effectiveness of the maneuver in increasing intra-bolus pressures in the pharynx (Bülow, Olsson & Ekberg, 1999; Bülow, Olsson & Ekberg, 2001; Bülow, Olsson & Ekberg, 2002; Hind, Nicosia, Roecker, Carnes & Robbins, 2001; Huckabee & Steele, 2006; Steele & Huckabee, 2007)). The most recent of these studies suggest that the manner of effortful swallow execution may be critical to the resulting effect; specifically, Huckabee and Steele (Huckabee & Steele, 2006; Steele & Huckabee, 2007) have shown that a greater increase in pharyngeal pressures can be achieved by incorporating an emphasis on pressing the tongue hard into the palate at the initiation of the

1 effortful swallow . The recommended instruction for this *tongue-pressure emphasis effortful*
 2 *swallow* would be to “swallow hard; to do this, start the swallow by pushing your tongue hard
 3 against the roof of your mouth”. Using this technique, the intervals between pressure peaks
 4 measured at progressively more distal sensors along the oropharyngeal tract are reported to
 5 shorten, suggesting that the pressure wave that is generated with the tongue-pressure emphasis
 6 effortful swallow is propagated more rapidly than in non-effortful swallows (Steele & Huckabee,
 7 2007).

8 Over the past decade, there has been an increasing interest in the swallowing literature on
 9 tongue-pressure and its contribution to swallowing. In a study by Nicosia and colleagues (2000),
 10 10 healthy seniors had significantly reduced maximum isometric tongue-pressure (an indicator of
 11 tongue strength) compared to 10 younger adults. Interestingly, however, Nicosia et al.’s (2000)
 12 data suggested that an age-related reduction in tongue strength is *not* seen in the pressures that
 13 are generated during swallowing tasks (“*swallowing pressures*”). Rather, it is the difference in
 14 amplitude between habitual swallowing pressures and maximum isometric capacity (called
 15 *functional reserve*) that is thought to decline in healthy aging (Ney, Weiss, Kind & Robbins,
 16 2009). Recently, however, evidence of an age-related decline in functional reserve has been
 17 called into question based on a larger study (n = 96) by Youmans, Youmans and Stierwalt
 18 (2009), who reported a significant age-related decline in maximum isometric pressure values
 19 measured using a single air-filled bulb held in the anterior oral cavity, but found that older
 20 participants and younger participants used the same proportion of their maximum isometric
 21 capacity in swallowing. Youmans et al., (2009) also observed a significant gender difference in
 22 swallowing pressures, with women producing higher pressures (and a higher percentage of their
 23 maximum isometric range) during swallowing tasks.

Age-related reductions in maximum isometric-tongue pressures suggest that changes are occurring in the tongue musculature with age, and implies that other muscles in the floor-of-mouth and pharynx may undergo similar changes (McComas, 1998). Surface electromyography (sEMG) has been used as an indirect non-invasive method for measuring swallowing strength and for providing biofeedback to patients during treatment (Crary, 1995; Crary, Carnaby Mann, Groher & Helseth, 2004; Crary & Groher, 2000; Huckabee & Cannito, 1999). There is a paucity of studies in which age-related changes in submental sEMG measures of swallowing have been explored. One study by Vaiman, Eviatar and Segal (2004) reported significant age-related reductions in raw submental sEMG amplitudes during regular effort saliva swallows and water swallows collected from 420 healthy adults (age 18-78); these results are difficult to compare to other studies because the investigators reported raw sEMG values rather than normalizing them to some comparable level (Ding, Logemann, Larson & Rademaker, 2003; Huckabee, Garcia & Barofsky, 1996; Perlman, 1993). Another study of 20 healthy older adults (age 65-85) compared to 20 younger adults (18-28) failed to find statistically significant differences in normalized submental sEMG amplitudes with 9 different stimuli, varying in taste and consistency (Ding, Logemann, Larson & Rademaker, 2003). It therefore remains unclear whether age-related changes occur in sEMG measures of swallowing function.

In this study, lingual pressure and submental sEMG reference data were collected for both effortful and non-effortful saliva swallows from a large sample of healthy women in two age groups. Specifically, this study examined whether differences in lingual pressure and sEMG occur during non-effortful swallows when comparing younger and older women. Given previous data suggesting preservation of functional reserve in tongue pressures with age, it was hypothesized that any age-related differences in amplitudes would be seen only in the sEMG

data; this would imply that age-related changes do not uniformly affect the different muscles and structures involved in swallowing. Our second goal was to determine whether age-related changes are present in the specific context of effortful saliva swallows. This question introduces the concept of *swallowing reserve* (i.e. the difference between habitual swallowing and effortful swallowing) in contrast to functional reserve. It is important to determine whether swallowing reserve is preserved in healthy aging, or whether it is susceptible to age-related decline similar to that seen in functional reserve. Our hypothesis was that age-related reductions would be seen in swallowing reserve, in the form of a significant age-group by task interaction, showing reduced amplitudes in lingual pressure and sEMG in older participants on the effortful swallowing task.

In addition to studying differences in saliva swallow amplitudes and swallowing reserve, we were interested in examining the temporal characteristics of lingual pressure and sEMG during effortful and non-effortful swallows. Steele and Huckabee (2007) have previously reported that rise-time durations (the interval between event onset and peak) become prolonged in the effortful saliva swallow in healthy young adults. Steele and Van Lieshout (2009) have found significantly longer durations of tongue movement in swallowing in healthy older adults, relative to younger controls, consistent with other reports in the motor control literature suggesting general motor slowing in the elderly (Morgan et al., 1994). It was therefore hypothesized that older participants in this study would show prolonged rise-times in both signals and both tasks relative to younger controls, and that effortful saliva swallows would be characterized by longer rise-times than non-effortful swallows in both groups.

This study was part of a larger project known as the Arkansas Taste and Swallowing Study (ARTSS). The primary focus of the ARTSS was to answer questions about the effects of taste and chemesthesis on swallowing function, using various taste stimuli and controlling for

genetic variations in taste. Genetic taste status is known to vary in a more extreme manner in women (Bartoshuk, Duffy & Miller, 1994; Pelletier & Dhanaraj, 2006); consequently, participation in the ARTSS was restricted to healthy adult women. Non-effortful and effortful saliva swallows were included as a baseline task during ARTSS data collection and were used for the current analysis. Genetic taste status was not expected to influence tongue pressures or sEMG measures during saliva swallows.

Methods

Participants

Participants in the ARTSS were recruited on the basis of perceived bitterness ratings for the chemical 6-*n*-propylthiouracil (PROP); this was tested in an initial pool of 222 volunteers in order to identify a study sample that was balanced for age-group (18-35 years; ≥ 60 years) and taste status. All participants lived independently in the community, reported no history of taste or swallowing difficulties, and had a score of ≥ 25 on the Mini Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975). One older participant was excluded based on extremely delayed response patterns and a need for numerous repetitions of instructions, suggesting probable cognitive impairment despite a passing MMSE score of 25. One hundred twenty-five participants were accepted; fifteen were ultimately excluded due to scheduling difficulties and 30 were excluded because the quota in their age/genetic taste group was met. Eighty women (40 in the younger age-group, mean = 26 $\pm$ 4 years of age; 40 in the older age-group, mean = 72 $\pm$ 8 years of age) participated in the experiment.

Data Collection

All data for the ARTSS were collected at the University of Arkansas for Medical Sciences under the direct supervision of the third author (CAP). Data were gathered on the

1 KayPentax Digital Swallow Workstation (DSW, Model 7200, Kay Swallowing Signals Lab
2 Model 7120). Swallowing data were simultaneously recorded from two channels: (1) lingual
3 pressure via two intraoral manometry transducers, (2) collective submental muscle activity via
4 sEMG. Manometry data were collected using two bulbs from the manufacturer's three-bulb
5 spineless tongue bulb array (13 mm bulb diameter, 8 mm inter-bulb distance). The bulb arrays
6 were modified, such that the third bulb was cut off to reduce any discomfort due to small mouth
7 size (Pelletier & Dhanaraj, 2006). The resulting 2-bulb lingual bulb array was attached to the
8 participant's palate using a strip of Stomahesive adhesive, and placed in an anterior-posterior
9 orientation, starting immediately posterior to the teeth and ending just behind the midpoint of the
10 hard palate. It should be noted that the modification of this bulb array and the resulting
11 placement means that pressures were registered in locations that may differ to some degree from
12 those used in prior studies (e.g. Huckabee & Steele, 2006). These bulb locations are referred to
13 as anterior-palate and mid-palate throughout the remainder of this manuscript. Furthermore, it
14 should be recognized that fixed inter-bulb distance means that the mid-palate bulb location may,
15 in fact, capture pressures from functionally different locations across participants with different
16 mouth sizes. Pressure data were acquired at a sampling rate of 250 Hz, and an upper recording
17 limit of 500 mm Hg. Pressure sensor calibration, according to manufacturer instructions, was
18 performed at the beginning of each data collection session. The time-linked surface EMG
19 measures were collected at a sampling rate of 1000 Hz and an upper recording limit set at 200
20 μ V using a triode patch of electrodes. The positive and negative electrodes were placed in
21 midline under the chin, equidistant from the angle of the neck and the genium, and the reference
22 electrode positioned laterally on one side. It should be noted that the EMG electrode placement

used in this study was consistent with that used in previous studies (Huckabee & Steele, 2006; Steele & Huckabee, 2007), but differs from that used by Vaiman, Eviatar and Segal (2004).

After all sensors were attached, a brief adaptation period was allowed while the signal quality was confirmed on the equipment monitor. The baseline task was then performed, on command, within a 5 minute time-frame, and always in the same order: three non-effortful saliva swallows followed by a single effortful saliva swallow. The protocol then continued with additional swallowing tasks, which will be reported separately. Task instructions for the non-effortful saliva swallow were to “swallow your saliva normally”, taking time between swallows to allow saliva replenishment. For the effortful saliva swallow task, participants were instructed to “Put your tongue behind your upper teeth and feel that ridge there? That is where your tongue normally goes when you take a swallow. It pushes the food or liquid back into your throat. Put your tongue behind your upper teeth and push hard as you swallow.” It should be noted that this instruction differs from that used previously by Bülow, Olsson and Ekberg (1999; 2001; 2002), who instructed participants to move their tongues in an upward-backward motion, towards the soft-palate, when executing the effortful swallow. The target location of the alveolar ridge was chosen in this study in order to be consistent with that used by Huckabee and Steele (2006), and based on recent literature regarding tongue movements in swallowing, which shows that the movement trajectory of the tongue is in an upward and forward direction during the oral phase of swallowing (Martin, 1991; Steele & van Lieshout, 2004; Steele & van Lieshout, 2009).

Data Processing

Data for some participants were incomplete for a variety of reasons. For one older participant, recording error resulted in an absence of all data for the baseline tasks of interest. SEMG data were similarly missing for one younger participant. Effortful swallow data were not

available due to recording errors or signal quality concerns, which made it impossible to clearly discriminate events in the pressure waveform for 6 participants (5 younger, 1 older) and in the sEMG waveform for 7 participants (5 younger, 2 older). The final dataset included complete tongue-pressure data from 73 participants, and complete sEMG data from 71 participants. Waveform characteristics were analyzed for each swallow. The onsets and peaks of waveform deflection from baseline were indexed using a cursor function on the DSW, and timing and amplitude measures for each indexed event were extracted using the DSW software. Two independent raters analyzed 10% of randomly selected data for reliability. Intra-class correlations showed good agreement between two raters ($ICC = 1.0$) for all event comparisons.

For each tongue-pressure bulb (anterior-palate and mid-palate), pressure amplitudes were recorded at the onset and the peak of waveform deflections from baseline. Pressure rise-time (i.e. the time between onset and peak amplitude, in milliseconds) was derived from the timepoints of pressure onsets and peaks. The sEMG signal amplitude was obtained at the signal onset and peak. EMG rise-time was calculated similarly to the lingual pressure data. Pressure and sEMG amplitudes were measured at the peak amplitude of the swallowing event. Prior to analysis, raw data values for the EMG data were normalized relative to the maximum value obtained during the 3 non-effortful saliva swallows (which was assigned a value of 100). Similarly, the raw data values for the tongue-pressure data (in mm Hg) were normalized relative to the maximum value obtained during the 3 non-effortful saliva swallows (assigned a value of 100). This normalization was performed separately for data collected at the anterior-palate bulb and for data collected at the mid-palate bulb. For clarity, the units for reporting normalized sEMG data and pressure data will be denoted as μV^N and $mm\ Hg^N$, respectively.

Analysis

Prior to proceeding with the analysis, the data were explored to determine whether there was a significant trial effect in amplitudes registered across the 3 non-effortful saliva swallows. Repeated measures analyses of variance (ANOVA) were performed separately for each type of data (anterior-palate pressure; mid-palate pressure; sEMG) with a within-participant factor of repetition (1st, 2nd and 3rd) and an alpha level of $p < 0.05$. No significant differences in amplitude were detected across task repetitions for any parameter. Consequently, each participant's average non-effortful saliva swallow sEMG and tongue-pressure amplitude values were used in the subsequent analyses.

To examine the effects of task and age-group differences, mixed model ANOVAs were performed in SPSS 17.0, with a between-participant factor of age-group (young, older) and controlling for the within-participant factor of task (non-effortful, effortful) by including random effects for participant and the participant X task interaction, with a variance components covariance structure and restricted maximum likelihood estimation. For the tongue-pressure data, the analyses were performed separately by bulb location (anterior, mid-palate). Log transformed data were used in the analyses given the fact that the non-transformed data were not normally distributed. An alpha-level of 0.025 was used ($0.05/2$) in recognition of the possible non-independence of the dependent variables (lingual pressure; sEMG) (Stevens, 2002). Effect sizes for statistically significant differences were calculated using the Cohen's d statistic (Kotrlík & Williams, 2003).

Results

Descriptive and inferential statistical results for tongue-pressure and sEMG amplitudes are shown by task and age-group in Table 2. No significant age-group by task interactions were

observed. A significant main effect of task was found for both the anterior and mid-palate tongue-pressure and for the sEMG data, with higher amplitudes in the effortful saliva swallow task. Figure 1 illustrates these task effects.

Descriptive and inferential statistical results for rise-time are shown in Table 3 by task and participant age-group. Two-factor interactions were not significant. Significantly longer pressure rise-times were found in the older participants at the anterior-palate bulb (830 vs. 610 ms) and at the mid-palate bulb (590 vs. 461 ms). Age effects were not seen in the sEMG data, although these approached the Bonferroni-corrected alpha criterion for significance at $p = 0.037$ with longer rise-times seen this time in the younger participants (836 vs. 748 ms). Significantly longer rise-times were seen during the effortful saliva swallow task for the anterior- and mid-palate pressures, but not in the sEMG data.

Discussion

The results of this study concur with previous studies showing no significant differences in swallow pressures or sEMG amplitudes between younger and older participants (Ding, Logemann, Larson & Rademaker, 2003; Nicosia et al., 2000; Youmans, Youmans & Stierwalt, 2009). We observed a trend towards age-related reductions in sEMG amplitudes, but these did not meet our criterion for statistical significance. Vaiman, Eviatar and Segal (2004) reported that older participants had reduced sEMG amplitudes than younger adults; the difference in results between these studies may be attributable to the fact that our data were normalized to control for across-participant variations in raw sEMG amplitude values and to the stringency of our criteria for statistical significance. Furthermore, electrode location differed in this study from that used by Vaiman et al. (2004).

The absence of any age-group by task interactions in lingual pressure or sEMG data refutes our second hypothesis and suggests that swallowing reserve is preserved with age. This further clarifies that elderly people should have the capacity to modulate tongue pressures for swallowing within the normal functional range in swallowing, despite any age-related changes in functional reserve that might exist. Our participants, both young and elderly, demonstrated the ability to significantly increase both tongue-palate pressures and submental sEMG amplitudes in the effortful saliva-swallowing task (compared to non-effortful swallows), with strong effect size. These results support the conclusions drawn by previous researchers (Huckabee & Steele, 2006) that the effortful swallow maneuver elicits greater submental muscle action and intraoral pressure. Maximum isometric tasks were not collected in this study; we are therefore unable to confirm or refute the existence of age-related changes in functional reserve, nor to comment on the percent of maximum isometric range that was used by our participants in the experimental tasks.

With respect to signal durations, it had been hypothesized that older participants would exhibit longer rise-times for effortful and non-effortful saliva swallows. This prediction was observed only in the anterior-palate pressure data (with moderate effect size), and not in the mid-palate pressure or sEMG waveforms. However, it should be noted that the standard deviations for rise-time at these two locations were large, particularly in the elderly participants. The observed variability may well obscure age-group differences in timing measures for these sensors, but because the variation was substantially greater than that seen in the younger participants, it suggests the possibility that timing differences in mid-palate tongue-pressure application and swallowing muscle activation may be a characteristic of senescent swallows. The previously-mentioned fact that our fixed pressure sensor configuration may register mid-palate

1 pressures at functionally different locations across different mouth sizes may contribute, in part,
2 to the substantial variability seen in pressure-timing at the mid-palate sensor. Additionally, it
3 should be noted that other studies have found pressures at the mid-palate to be more variable
4 than pressures at the anterior and posterior palate, perhaps indicating variation in the extent to
5 which contact is registered at the mid-palate across individuals with different palatal arch height
6 (Steele, Bailey & Molfenter, 2010).

7 Finally, it had been predicted that effortful swallows in both age-groups would exhibit
8 longer rise-times, consistent with previous work by Steele and Huckabee (2007), who found that
9 rise-time to peak amplitude was significantly longer in the effortful saliva swallowing task. This
10 prediction was confirmed for both tongue-palate pressure sensors in our study. The larger effect
11 size for this finding at the anterior palate suggests a particular importance of anterior-palate
12 pressures in swallowing initiation. A trend towards the predicted effect was also noted in the
13 sEMG data, but this did not meet our criterion for statistical significance.

14 In conclusion, the current data contribute additional evidence to the literature regarding
15 the effects of aging on swallowing, and specifically on swallowing reserve. The data confirm that
16 differences between the effortful and non-effortful swallow can be seen in sEMG and orolingual
17 manometry signals. Effortful swallows were found to produce larger signal amplitudes in both
18 the lingual pressure and submental sEMG data. Effortful swallows were also found to result in
19 increased durations from signal onset to peak for tongue-palate pressures, but not for submental
20 muscle contraction.

21 The durational data suggest that the anterior tongue-palate pressures play a greater role in
22 the execution of the effortful swallow, for both age groups, than mid-palate pressures or
23 submental muscle contraction. This is particularly interesting when compared with results from

Huckabee and Steele (2006), who found that lingual emphasis (as opposed to pharyngeal emphasis) produced greater pharyngeal pressures while participants performed the effortful swallowing task. Taken together, these data suggest that tongue-palate pressure is particularly important in generating effortful swallow. However, it must be recognized that the experimental task instructions, both in this study and the preceding work by Huckabee and Steele (2006) may have directly contributed to this finding based on the instructional emphasis on pushing hard with the tongue during performance of the effortful swallowing maneuver.

Finally, in terms of the impact age has on the effortful swallow, the results showed that there are no significant differences in the amplitudes of lingual pressure and sEMG signals produced by older and younger healthy women. This lends further credence to the idea that non-effortful and effortful swallows can still be produced with similar lingual pressures and submental muscle involvement in older women, despite any general age-related deterioration of swallowing musculature that may exist due to the phenomenon of sarcopenia (Ney, Weiss, Kind & Robbins, 2009). This evidence corroborates previous findings showing that reductions in strength do not affect swallowing (Nicosia et al., 2000; Youmans, Youmans & Stierwalt, 2009). Specifically, both habitual swallowing and swallowing reserve measures remained resilient in the healthy older participants involved in this study. This suggests that future research in the burgeoning area of exercise-based interventions for swallowing needs to continue to probe the extent that functional muscle reserve is critical for completing swallowing tasks. The present data suggest that age-related differences are seen in durational aspects of tongue-palate pressure application. Treatment protocols that emphasize the restoration of normal timing rather than increasing maximum strength would be more logically supported by the results of this study.

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1 *Table 1.* Comparison of the methods and results of previous studies of the effortful swallow.

<i><u>Study</u></i>	<i><u>Population</u></i>	<i><u>Technique</u></i>	<i><u>Instruction</u></i>	<i><u>Finding</u></i>
Bülow, Olsson & Ekberg, 1991	8 healthy adults, mean age 41 years	Videomanometry; comparison of 3 non-effortful and 3 effortful thin liquid barium swallows. Also examined other techniques (supraglottic swallow and chin-tuck).	“Swallow very hard while squeezing the tongue in an upward-backward motion toward the soft palate”.	No significant differences in manometric or biomechanical measures. Conspicuous pre-elevation of the hyoid bone was noted during the effortful swallow.
Bülow, Olsson & Ekberg, 2001	8 patients with pharyngeal dysfunction (3 moderate; 5 severe). Mean age of 70.	As above.	As above.	No significant differences in peak pharyngeal or upper esophageal sphincter contraction pressures. No differences in biomechanical measures. Pre-elevation of the hyoid noted in the effortful swallow.
Bülow, Olsson & Ekberg, 2002	As above.	As above.	As above.	No significant differences in peak intra-bolus pressure amplitudes or pressure durations.
Hind, Nicosia, Roecker, Carnes & Robbins, 2001	Healthy adults: 20 participants randomly selected for age comparisons (younger group aged 48-55; older group aged 69-91).	Videofluoroscopy and concurrent intra-oral manometry; comparison of 2 non-effortful and 2 effortful thin liquid barium swallows	“Swallow hard”	No significant differences in durational or biomechanical measures. Trend towards reduced residue in the valleculae and pyriform sinuses with the effortful swallow. Trend towards smaller pressure increase for effortful swallow in older group.

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1 *Table 1. (continued)*

<u><i>Study</i></u>	<u><i>Population</i></u>	<u><i>Technique</i></u>	<u><i>Instruction</i></u>	<u><i>Finding</i></u>
Huckabee & Steele, 2006	20 healthy young adults (20-35 years).	Combined submental surface EMG, intra-oral and pharyngeal manometry. Reiterated sets of 5 non-effortful and effortful saliva swallows compared. Study also examined Mendelsohn maneuver.	1) pharyngeal-pressure emphasis: “as you swallow, squeeze hard with the muscles of your throat but do NOT use your tongue to generate extra force”; 2) tongue-pressure emphasis: “as you swallow, push really hard with your tongue”	Negligible changes in pressure or EMG measures in pharyngeal-pressure emphasis condition. Significant increases in pressures measured at all sites in tongue-pressure emphasis condition.
Steele & Huckabee, 2007	As above.	As above.	As above.	Significantly faster pressure-wave propagation (i.e., shortened intervals between pressure peaks from sensor to sensor) in tongue-pressure emphasis condition. Significantly longer pressure and EMG rise-times in the effortful swallow compared to non-effortful swallows.

1 *Table 2. Descriptive and inferential statistical results for EMG and tongue-pressure amplitudes, by sensor, task and age-group.*

<i>Parameter</i>	<i>Age-group</i>	<i>Non-Effortful Saliva Swallows</i>		<i>Effortful Saliva Swallows</i>		<i>Comparison</i>	<i>F</i>	<i>df</i>	<i>p</i>	<i>Effect size (Cohen's d)*</i>
		<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>					
Anterior-Palate Tongue-pressure (mm Hg ^N)	Young	155.33	73.63	302.47	134.08	Age-Group	0.07	1, 76.58	0.788	0.1
	Older	126.92	61.04	295.68	115.97					
	Total	141.3	68.78	298.89	124.03	Task	169.56	1, 73.887	0.0000	1.25
Mid-Palate Tongue-pressure (mm Hg ^N)	Young	162.4	65.46	281.5	100.22	Age-Group	0.72	1, 74.561	0.399	0.12
	Older	166.09	74.36	297.4	101.9					
	Total	164.22	69.57	289.88	100.73	Task	144.22	1, 71.934	0.0000	1.17
Submental sEMG (μV ^N)	Young	84.1	12.01	204.76	165.45	Age-Group	4.38	1, 77.79	0.04	0.25
	Older	79.52	13.48	149.27	78.58					
	Total	81.81	12.89	175.47	129.3	Task	104.02	1, 76.557	0.000	0.91

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3 ^N denotes data that have been normalized relative to the maximum parameter value for each participant during the non-effortful saliva
 4 swallow tasks.

5 * Interpretation of the Cohen's *d* statistic is as follows: ≤ 0.5 = weak effect; 0.5-0.79 = moderate effect; ≥ 0.8 = strong effect.

Table 3. Descriptive and inferential statistical results for EMG and tongue-pressure rise-time (in milliseconds) shown by sensor, task and age-group

<i>Parameter</i>	<i>Age-group</i>	<i>Non-Effortful Saliva Swallows</i>		<i>Effortful Saliva Swallows</i>		<i>Comparison</i>	<i>F</i>	<i>df</i>	<i>p</i>	<i>Effect size (Cohen's d)*</i>
		<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>					
Anterior-Palate Tongue-pressure Rise-Time (ms)	Young	536	216	685	415	Age-Group	8.20	1, 78.31	0.005	0.43
	Older	670	318	970	781					
	Total	603	278	838	649	Task	8.56	1, 76.37	0.005	0.47
Mid-Palate Tongue-pressure Rise-Time (ms)	Young	451	254	529	481	Age-Group	1.88	1, 78.38	0.174	0.38
	Older	660	1179	691	774					
	Total	555	853	616	655	Task	8.62	1, 76.36	0.004	0.12
Submental sEMG Rise-Time (ms)	Young	730	338	958	527	Age-Group	4.52	1, 74.78	0.037	0.14
	Older	588	192	912	1039					
	Total	659	282	934	832	Task	3.04	1, 75.39	0.086	0.44

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4 * Interpretation of the Cohen's *d* statistic is as follows: ≤ 0.5 = weak effect; 0.5-0.79 = moderate effect; ≥ 0.8 = strong effect.

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1 Figure Captions:

2

3 *Figure 1.* Mean amplitudes (normalized) for lingual pressure and submental sEMG for effortful and non-effortful saliva swallows

4 averaged across participants from both age groups. Error bars = 1 SD.

1 *Figure 1.*

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